

**Q14.**

- (a) The concentration of iron(III) ions in a dilute solution can be determined by visible spectrometry. The absorption of light by a number of solutions of iron(III) sulfate, $\text{Fe}_2(\text{SO}_4)_3(\text{aq})$, was measured. The results are shown in the table below.

Concentration of $\text{Fe}_2(\text{SO}_4)_3(\text{aq})$ / mol dm ⁻³	Absorbance / %
0.020	2.2
0.040	4.7
0.060	7.0
0.080	9.4
0.100	11.8

- (i) Use these results to plot a graph of percentage absorbance (y-axis) against concentration of iron(III) sulfate solution on the grid below. Draw a straight line of best fit.



(2)

- (ii) Use your graph to determine the concentration of iron(III) ions in a solution of $\text{Fe}_2(\text{SO}_4)_3$ that has an absorbance of 5.4%.

(2)



- (iii) Calculate the volume of water that should be added to 100 cm³ of a 0.10 mol dm⁻³ solution of iron(III) sulfate to make a 0.040 mol dm⁻³ solution.
Show your working.

(2)

- (b) Give **one** reason why well-water may be more beneficial to health than pure water.

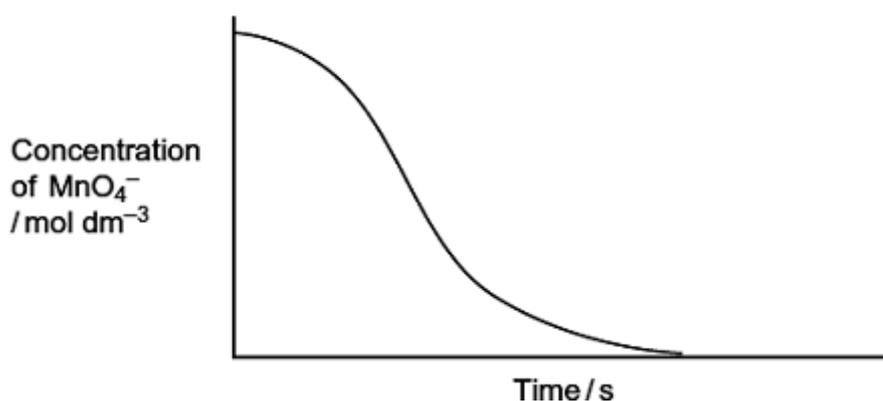
(1)

(Total 7 marks)

Q15.

An acidified solution of potassium manganate(VII) was reacted with a sample of sodium ethanedioate at a constant temperature of 60 °C. The concentration of the manganate(VII) ions in the reaction mixture was determined at different times using a spectrometer to measure the light absorbed.

The following results were obtained.



- (a) Write an equation for the reaction between manganate(VII) ions and ethanedioate ions in acidic solution.

(2)



- (b) By considering the properties of the reactants and products, state why it is possible to use a spectrometer to measure the concentration of the manganate(VII) ions in this reaction mixture.

(2)

- (c) This reaction is autocatalysed. Give the meaning of the term *autocatalyst*. Explain how the above curve indicates clearly that the reaction is autocatalysed.

Meaning of *autocatalyst* _____

Explanation _____

(3)

- (d) Identify the autocatalyst in this reaction.

(1)

- (e) Write **two** equations to show how the autocatalyst is involved in this reaction.

Equation 1 _____

Equation 2 _____

(2)

(Total 10 marks)

**Q16.**

This question is about copper chemistry.

(a) Aqueous copper(II) ions $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ are blue.

(i) With reference to electrons, explain why aqueous copper(II) ions are blue.

(3)

(ii) By reference to aqueous copper(II) ions, state the meaning of each of the **three** terms in the equation $\Delta E = h\nu$.

(3)

(iii) Write an equation for the reaction, in aqueous solution, between $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ and an excess of chloride ions.
State the shape of the complex produced and explain why the shape differs from that of the $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ ion.

(3)



- (b) Draw the structure of the ethanedioate ion ($\text{C}_2\text{O}_4^{2-}$). Explain how this ion is able to act as a ligand.

(2)

- (c) When a dilute aqueous solution containing ethanedioate ions is added to a solution containing aqueous copper(II) ions, a substitution reaction occurs. In this reaction four water molecules are replaced and a new complex is formed.

- (i) Write an ionic equation for the reaction. Give the co-ordination number of the complex formed and name its shape.

(4)



- (ii) In the complex formed, the two water molecules are opposite each other. Draw a diagram to show how the ethanedioate ions are bonded to a copper ion and give a value for one of the O–Cu–O bond angles. You are **not** required to show the water molecules.

(2)

(Total 17 marks)

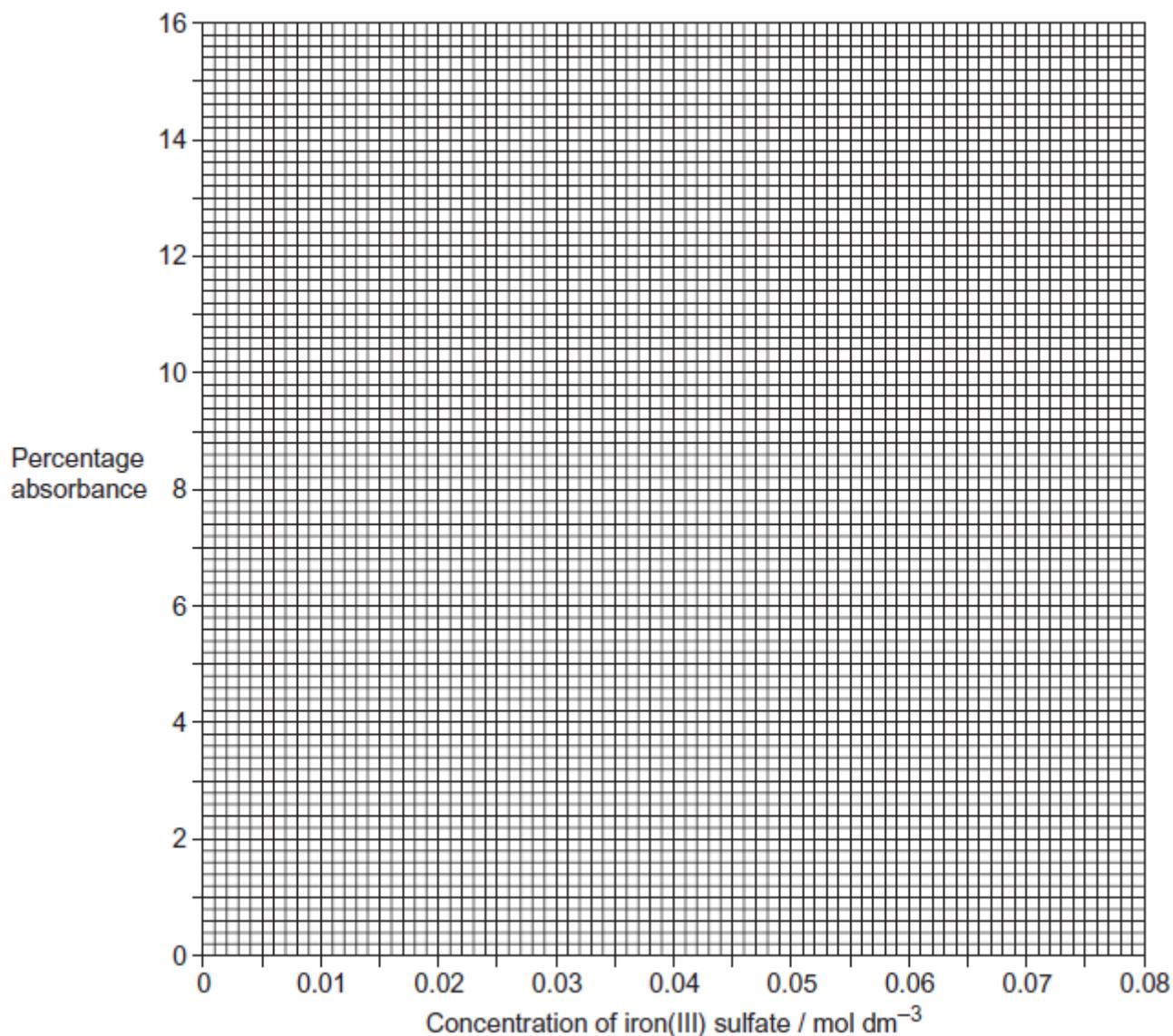
Q17.

The concentration of iron(III) ions in a dilute solution can be determined by visible spectrometry. The absorption of light of a particular frequency by solutions of iron(III) sulfate of different concentrations was measured. The results are shown in the table below.

Percentage absorbance	Concentration of iron(III) sulfate / mol dm ⁻³
1.0	7.5 × 10 ⁻³
2.5	14.0 × 10 ⁻³
5.0	27.5 × 10 ⁻³
7.0	37.5 × 10 ⁻³
10.0	54.0 × 10 ⁻³
12.0	65.0 × 10 ⁻³



- (a) Use these results to plot a graph of percentage absorbance (y-axis) against concentration of iron(III) sulfate on the grid below. Draw a straight line of best fit.



(2)

- (b) Use your graph to determine the concentration of an iron(III) sulfate solution that has a percentage absorbance of 14.0%.

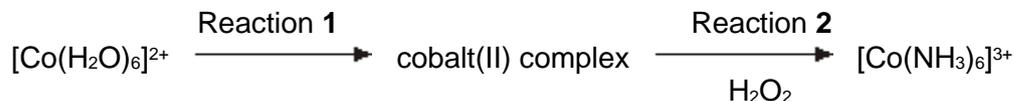
(1)

(Total 3 marks)

**Q18.**

Hydrogen peroxide is used as an oxidising agent in the preparation of transition metal complexes.

- (a) Consider the following reaction scheme. All the complexes are in aqueous solution.



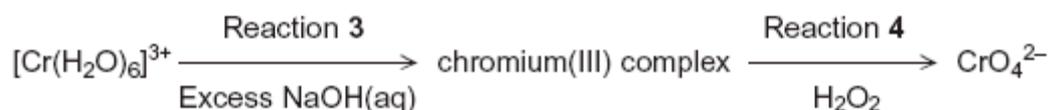
- (i) Identify a reagent for Reaction 1 and describe the colour change that occurs.

(3)

- (ii) State the colour of the final solution formed in Reaction 2.

(1)

- (b) Consider the following reaction scheme. All the complexes are in aqueous solution.



- (i) For Reaction 3, state the colour of the initial and of the final solution and write an equation for the reaction.

(4)

- (ii) Write a half-equation for the reduction of hydrogen peroxide to hydroxide ions.
Deduce an overall equation for Reaction 4 and state the colour of the final solution.

(4)

**Q19.**

Calcium fluoride occurs naturally as the mineral fluorite, a very hard crystalline solid that is almost insoluble in water and is used as a gemstone.

Tables 1 and 2 contain thermodynamic data.

Table 1

Process	$\Delta H^\circ / \text{kJ mol}^{-1}$
$\text{Ca(s)} \rightarrow \text{Ca(g)}$	+193
$\text{Ca(g)} \rightarrow \text{Ca}^+(\text{g}) + \text{e}^-$	+590
$\text{Ca}^+(\text{g}) \rightarrow \text{Ca}^{2+}(\text{g}) + \text{e}^-$	+1150
$\text{F}_2(\text{g}) \rightarrow 2\text{F}(\text{g})$	+158
$\text{F}(\text{g}) + \text{e}^- \rightarrow \text{F}^-(\text{g})$	-348

Table 2

Name of enthalpy change	$\Delta H^\circ / \text{kJ mol}^{-1}$
Enthalpy of lattice dissociation for calcium fluoride	+2602
Enthalpy of lattice dissociation for calcium chloride	+2237
Enthalpy of hydration for F^- ions	-506
Enthalpy of hydration for Cl^- ions	-364
Enthalpy of hydration for Ca^{2+} ions	-1650

- (a) Write an equation, including state symbols, for the process that occurs when the calcium fluoride lattice dissociates and for which the enthalpy change is equal to the lattice enthalpy.

(1)

- (b) (i) Define the term *standard enthalpy of formation*.

(3)



- (ii) Write an equation, including state symbols, for the process that has an enthalpy change equal to the standard enthalpy of formation of calcium fluoride.

(1)

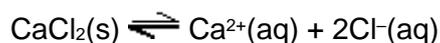
- (iii) Use data from the **Tables 1** and **2** to calculate the standard enthalpy of formation for calcium fluoride.

(3)

- (c) Explain why the enthalpy of lattice dissociation for calcium fluoride is greater than that for calcium chloride.

(2)

- (d) Calcium chloride dissolves in water. After a certain amount has dissolved, a saturated solution is formed and the following equilibrium is established.



- (i) Using data from **Table 2**, calculate the enthalpy change for this reaction.

(2)



- (ii) Predict whether raising the temperature will increase, decrease or have no effect on the amount of solid calcium chloride that can dissolve in a fixed mass of water. Explain your prediction.
(If you have been unable to obtain an answer to part (d) (i), you may assume that the enthalpy change = -60 kJ mol^{-1} . This is **not** the correct answer.)

Effect on amount of solid that can dissolve _____

Explanation _____

(3)

- (e) Calcium fluoride crystals absorb ultra-violet light. Some of the energy gained is given out as visible light. The name of this process, fluorescence, comes from the name of the mineral, fluorite.

Use your knowledge of the equation $\Delta E = h\nu$ to suggest what happens to the electrons in fluorite when ultra-violet light is absorbed and when visible light is given out.

(2)

(Total 17 marks)



Mark Scheme

Q14.

- (a) (i) Correctly plots all points (\pm one square) and draws straight line of best fit
Lose this mark if the candidate's line is doubled or kinked.
Lose this mark if the line does not pass within one square of the origin, extending the line if necessary. 1
- Plotted points cover over half of grid 1
- (ii) 0.046 ± 0.002 (mol dm⁻³) 1
- 0.088 to 0.096 (mol dm⁻³)
Allow M1 \times 2
Allow two marks for correct answer.
Answer must be to at least two significant figures. 1
- (iii) Total volume = $(100 \times 0.1) / 0.04 = 250$ (cm³)
Allow any correct alternative method of working. 1
- Therefore add 150 cm³
Correct answer without working scores M2 only. 1
- (b) Iron needed for haemoglobin / for red blood cells / to carry oxygen around the body
Accept well-water may contain eg Ca²⁺ ions / dissolved minerals that are good for bones / teeth etc. 1

[7]

Q15.

- (a) $2\text{MnO}_4^- + 16\text{H}^+ + 5\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 10\text{CO}_2$
For all species correct / moles and species correct but charge incorrect 1
- For balanced equation including all charges (also scores first mark)* 1
- (b) Manganate(VII) ions are coloured (purple) 1
- All other reactants and products are **not** coloured (or too faintly coloured to detect)
Allow (all) other species are colourless
Allow Mn²⁺ are colourless / becomes colourless / pale pink 1



- (c) The catalyst for the reaction is a reaction product 1
- Reaction starts off slowly / gradient shallow 1
- Then gets faster/rate increases / gradient increases
Allow concentration of MnO_4^- decreases faster / falls rapidly 1
- (d) Mn^{2+} ions 1
Allow Mn^{3+} ions
- (e) $MnO_4^- + 8H^+ + 4Mn^{2+} \rightarrow 5Mn^{3+} + 4H_2O$ 1
Allow multiples
- $2Mn^{3+} + C_2O_4^{2-} \rightarrow 2Mn^{2+} + 2CO_2$ 1

[10]

Q16.

- (a) (i) absorbs (certain frequencies of) (white) light / photons 1
not absorbs white / u.v. light
- d electrons excited / promoted 1
or d electrons move between levels / orbitals
d electrons can be implied elsewhere in answer
- the colour observed is the light not absorbed / light reflected / light transmitted 1
allow blue light transmitted
penalise emission of light in M3
- (ii) ΔE is the energy gained by the (excited) electrons (of Cu^{2+}) 1
allow:
 - energy difference between orbitals / sub-shells
 - energy of photon / light absorbed
 - change in energy of the electrons energy lost by excited electrons
 - energy of photon / light emitted
- h (Planck's) constant 1
- ν frequency of light (absorbed by $Cu^{2+}(aq)$) 1
do not allow wavelength
If energy lost / photon lost / light emitted in M1 do not penalised



light emitted

1



note that $[\text{CuCl}_4]^{2-}$ is incorrect

penalise charges shown separately on the ligand and overall

penalise HCl

1

tetrahedral

1

Cl^- / Cl / chlorine too big (to fit more than 4 round Cu)

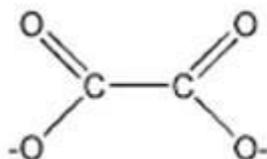
allow

water smaller than Cl^-

explanation that change in shape is due to change in co-ordination number

1

(b)



allow:

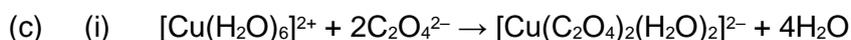
- ion drawn with any bond angles*
- ion in square brackets with overall / 2- charge shown outside the brackets*
- ion with delocalised $\text{O}=\text{C}-\text{O}$ bonds in carboxylate group(s)*

1

lone pair(s) on O^- / O

allow position of lone pair(s) shown on O in the diagram even if the diagram is incorrect.

1



product correct

1

equation balanced

1

6

note can only score M3 and M4 if M1 awarded or if complex in equation has 2 waters and 2 ethanedioates

1

octahedral

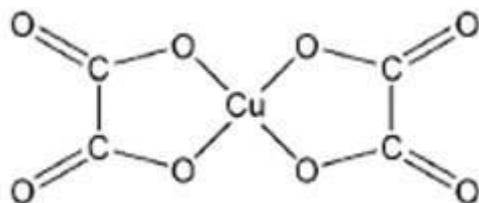
If this condition is satisfied the complex can have the



wrong charge(s) to allow access to M3 and M4 but not M1

1

(ii)



ignore charges

diagram must show both ethanedioates with correct bonding

ignore water

1

90°

allow 180°

mark bond angle independently but penalise if angle incorrectly labelled / indicated on diagram

1

[17]

Q17.

- (a) Plots all of the points correctly \pm one square

1

Straight line through the points is best fit

Candidate does not have to extrapolate line to the origin.

Line must pass through the origin \pm 1 square.

Lose this mark if the candidate's line is doubled or kinked.

Allow line that doesn't pass through the origin if one or more points are misplotted.

1

- (b) $7.6 \pm 0.1 \times 10^{-2}$ (mol dm⁻³)

Do not penalise precision, but at least 2 significant figures.

1

[3]

Q18.

- (a) (i) Ammonia

If reagent is missing or incorrect cannot score M3

1

Starts as a pink (solution)

1

Changes to a yellow/straw (solution)

Allow pale brown

Do not allow reference to a precipitate

1



- (ii) (dark) brown
Do not allow pale/straw/yellow-brown (i.e. these and other shades except for dark brown)
 1
- (b) (i) Ruby/red-blue/purple/violet/green
Do not allow red or blue
If ppt mentioned contradiction/CE =0
 1
- Green
If ppt mentioned contradiction/CE =0
 1
- $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{OH}^- \rightarrow [\text{Cr}(\text{OH})_6]^{3-} + 6\text{H}_2\text{O}$
 1
- Formula of product
Can score this mark in (b) (ii)
 1
- (ii) $\text{H}_2\text{O}_2 + 2\text{e}^- \rightarrow 2\text{OH}^-$
 1
- $2[\text{Cr}(\text{OH})_6]^{3-} + 3\text{H}_2\text{O}_2 \rightarrow 2\text{CrO}_4^{2-} + 8\text{H}_2\text{O} + 2\text{OH}^-$
Allow 1 mark out of 2 for a balanced half-equation such as Cr(III) \rightarrow Cr(VI) + 3e⁻
or Cr³⁺ + 4H₂O \rightarrow CrO₄²⁻ + 8H⁺ + 3e⁻ etc
also for 2Cr(III) + 3H₂O₂ \rightarrow 2CrO₄²⁻ (unbalanced)
 2
- Yellow
Do not allow orange
 1
- (c) $2\text{MnO}_4^- + 6\text{H}^+ + 5\text{H}_2\text{O}_2 \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{O}_2$
if no equation and uses given ratio can score M2, M3, M4 & M5
 1
- Moles $\text{MnO}_4^- = (24.35/1000) \times 0.0187 = \underline{4.55 \times 10^{-4}}$
Note value must be quoted to at least 3 sig. figs.
M2 is for 4.55×10^{-4}
 1
- Moles $\text{H}_2\text{O}_2 = (4.55 \times 10^{-4}) \times \underline{5/2} = 1.138 \times 10^{-3}$
M3 is for $\times 5/2$ (or 7/3)
Mark consequential on molar ratio from candidate's equation
 1
- Moles H_2O_2 in 5 cm³ original
M4 is for $\times 10$
 1
- $= (1.138 \times 10^{-3}) \times \underline{10} = 0.01138$



$$\text{Original } [\text{H}_2\text{O}_2] = 0.01138 \times \frac{1000}{5} = 2.28 \text{ mol dm}^{-3}$$

(allow 2.25-2.30)

M5 is for consequentially correct answer from (answer to mark 4) $\times (1000/5)$

Note an answer of between 2.25 and 2.30 is worth 4 marks)

If candidate uses given ratio 3/7 max 4 marks:

M1: Moles of $\text{MnO}_4^- = 4.55 \times 10^{-4}$

M2: Moles $\text{H}_2\text{O}_2 = (4.55 \times 10^{-4}) \times \frac{7}{3} = 1.0617 \times 10^{-3}$

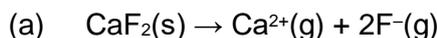
M3: Moles H_2O_2 in 5 cm^3 original
 $= (1.0617 \times 10^{-3}) \times 10 = 0.01062$

M4: Original $[\text{H}_2\text{O}_2] = 0.01062 \times (1000/5) = 2.12 \text{ mol dm}^{-3}$
 (allow 2.10 to 2.15)

1

[17]

Q19.



1

(b) (i) Enthalpy change for formation of 1 mol of substance

Allow heat energy change, NOT energy

1

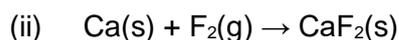
From its elements

1

Reactants and products/all substances in their standard states

Or normal states at 298 K, 1 bar (100 kPa)

1



1

(iii) $\Delta H_f(\text{CaF}_2) = \Delta H_a(\text{Ca}) + 1\text{st IE}(\text{Ca}) + 2\text{nd IE}(\text{Ca}) + \text{BE}(\text{F}_2) + 2 \times \text{EA}(\text{F}) - \Delta H_L(\text{CaF}_2)$

Or labelled diagram

1

$$= 193 + 590 + 1150 + 158 + (2 \times -348) - 2602$$

1

$$= -1207 \text{ kJ mol}^{-1}$$

Correct answer scores 3

-842 scores 2 (transfer error)

-859 scores 1 only (using one E.A.)

Units not required, wrong units lose 1 mark

1

(c) Electrostatic attraction stronger/ionic bonding stronger/attraction between ions stronger/more energy to separate ions

Molecular attraction/atoms/intermolecular forces $CE=0$

1



- Because fluoride (ion) smaller than chloride
Do not allow F or fluorine 1
- (d) (i) $\Delta H = \Delta H_L + \Sigma \Delta H_{\text{hyd}} = 2237 - 1650 + (2 \times -364)$
Can be on cycle/diagram 1
- $= -141 \text{ kJ mol}^{-1}$
Correct answer scores 2
Units not required, wrong units lose 1 mark 1
- (ii) Decreases
If ans to (d)(i) positive allow increases 1
- Reaction exothermic/ ΔH $-ve$
If (d)(i) +ve allow endothermic/ ΔH + ve 1
- (Equilibrium) shifts to left/backwards
 (as temperature rises)/equilibrium
 opposes the change
If (d) (i) +ve allow shifts to right/forwards/equilibrium opposes the change
If no answer to (d) (i) assume $-ve \Delta H$ used
If effect deduced incorrectly from any ΔH CE = 0 for these 3 marks 1
- (e) u.v. absorbed: electrons/they move to higher energy
 (levels)/electrons excited 1
- visible light given out: electrons/they fall back down/move to
 lower energy (levels)
Must refer to absorbing u.v. NOT visible light or this must be implied. 1

[17]